

THE INTERNAL ORGANS OF REPRODUCTION OF THE MALE SAW-FLY, *CIMBEX AMERICANA* LEACH.

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(WITH PLATE XII.)

HISTORICAL.

The male organs of reproduction of various Hymenoptera have been the object of study of a number of naturalists. Swammerdam (35), Réaumur (25), Dufour (10), Leydig (21), Leuckart* and more recently Cheshire (6), Koschewnikoff (20), Bordas (3), and Michaelis (22) have all worked on the reproductive organs of the drone bee. Schneider (31), in his general considerations upon the development of the reproductive organs of insects, has devoted some time to the Cynipidae and Ichneumonidae. Kluge (19) has worked on the male genital organs of *Vespa germanica*. Bordas (3) carried his research to several genera belonging to various families of Hymenoptera often not closely related. A number of other naturalists:—André (1), Schmiedeknecht (30), Hoffer (17), Radoszkowski (26, 27, 28), Verhoeff (37) and Zander (38, 39) have carried on their study on the external genital apparatus of various Hymenoptera.

A few authors have extended their investigations to different species of the family Tenthredinidae. Burmeister (32) figures and describes the external genital armature of *Cimbex variabilis*.

Dufour (10) described the anatomical relation of the reproductive organs of a number of species belonging to this family; viz., *Cephus pygmaeus*, *Tenthredo cincta*, *Tenthredo rustica*, and *Hylotoma enoides*. In *Cimbex* he describes the large accessory glands or glandulae mucosae as vesiculae seminales. In all the figures of the various species of Tenthredinidae he has made this same mistake.

After Dufour, Leuckart has treated in a general way the male reproductive organs of *Anthidium* and *Athalia*. Bordas (3) quotes nearly in-extenso his work which we reproduce as follows:—
"La structure des testicules consiste, chez les *Anthidium*, en une série de trois conduits séminifères qui se continuent par un canal déférent commun. Chez l'*Athalia*, ils sont constitués par une

* Paper not accessible

suite de poches arrondies. Les canaux déférents sont longs, grêles et s'entrelacent parfois pour former des testicules secondaires (*Athalia*). Les glandes accessoires, en forme de conduits terminés en cul-de-sac, s'insèrent à des hauteurs variables, le long des canaux déférents."

Raymond (29) in his work upon the organization of *Nematus ribesii* Scopoli has described, in a general way, the reproductive organs of this species. He writes, "Les vésicules séminales de ces insectes sont piriformes, au nombre de deux, et elles mesurent environ 1 millimètre de longueur; le canal déférent qui les surmonte est un tube court, s'anastomosant avec son voisin, après un faible parcours, pour former le canal éjaculateur qui s'ouvre entre les armatures sexuelles.

Près de leur partie postérieure et latéralement, chacune des vésicules porte un tube à parois transparentes et épaisses, ayant 0^{mm}07 de diamètre. Ces tubes, que nous n'avons pu suivre jusqu'à leur extrémité, représentent les testicules et ont une certaine analogie avec les ovaires des femelles. Les vésicules ont des parois très épaisses, vaguement fibreuses; elles sont très contractiles et contiennent un liquide laiteux chargé de globules arrondis et très petits. Malgré tous nos efforts, nous n'avons pu constater aucun mouvement propre à ces corpuscles."

A dissection of this species revealed to us that he has made the same mistake as Dufour, in calling the accessory glands or glandulae mucosae the seminal vesicles.

Packard (24) in his text book of entomology copied Newport's (23) figure of the male reproductive organs of the saw-fly, *Athalia centifoliae* but modified the description as follows:—

Newport's description.

- (a) The smaller testes.
- (b) The duct.
- (c) The large pair of testes. }
- (d) The efferential vessel. }
- (e) The vesiculae seminales.
- (f) The approximation of their ducts.
- (g) Extremity of the penis.
- (h) Ejaculatory duct.

Packard's description.

- a, a, testes.
- b, b, epididymis.
- c, d, vas deferentia.
- e, vesiculae seminales.
- f, ductus ejaculatorius.
- h, penis.

A comparative study of our work on *Cimbex americana* shows that the male reproductive organs are very similar to those of the saw-fly, *Athalia centifoliae* figured by Newport and copied by Packard. It appears to us that Packard in his revised explanation of Newport's figure has fallen in to the same error as Dufour,

calling the large accessory glands or glandulae mucosae, the vesiculae seminales. The vasa deferentia of Packard's explanation correspond to the vesiculae seminales of *Cimbex* and the epididymes to the vasa deferentia. Newport's description of the male reproductive organ of *Athalia centifoliae* is so far from correct that it is hardly worth consideration.

ANATOMICAL DESCRIPTION.

The male organs of reproduction of *Cimbex americana* consist of six principal parts:—the testes, the seminal ducts (vasa deferentia), the seminal vesicles, the accessory glands (glandulae mucosae), the ejaculatory ducts and the external genital armature.

The testes are paired (Fig. 1, t) and are situated on each side of the alimentary canal, in the sixth abdominal segment. They are kidney-shaped and are completely embedded in adipose tissue. When this adipose tissue is carefully dissected away, it is found that the testes are enveloped by a thin membrane ("capsule enveloppante" of Bordas (3)).

A number of tracheae originating from the fifth and sixth abdominal spiracles (Fig. 2, 5s and 6s) send off numerous branches which penetrate this membrane and hold the testes in their lateral position. One main trunk, which originates near the fifth abdominal stigma, gives off a number of branches to the anterior and of the testis (Fig. 2, tr); those tracheae which originate from the sixth abdominal spiracle send off, near the inner margin of the testis, numerous branches which divide and redivide, forming a network on the generative organ.

Each testis sends off from its inner median margin a very thin cylindrical tube, the vas deferens (Fig. 1, vd). Both vasa deferentia pass backward as straight tubes through the seventh abdominal segment and widen rather abruptly in the anterior region of the eighth segment to form the seminal vesicles. The seminal vesicles make several convolutions (Fig. 1, sv) and then communicate posteriorly with the large accessory glands (Fig. 1, o).

The accessory glands or glandulae mucosae are a pair of hooked glands with the distal ends enlarged and rounded, while the posterior portion of each gradually narrows into a duct (Fig. 1, gm). The two glandulae mucosae diverge and are obliquely inclined on each side of the anterior region of the rectum. These glands partly conceal the last abdominal ganglion, which sends nerves to them.

From an external view one cannot say with certainty just where the ducts of the glandulae mucosae end and the ejaculatory ducts begin. The latter are two short cylindrical tubes which continue side by side and only join at their terminal extremity to open to the outside. Zander (39) describes the ductus ejaculatorius of *Cimbex variabilis* as a "enges Rohr, das den Penis durchzieht."

HISTOLOGICAL DESCRIPTION.

Testis: A study of sections cut through the testis shows that the club-shaped testicular follicles are surrounded by a thin membrane ("capsule enveloppante" of Bordas) which contains small ovoid nuclei. Numerous tracheae penetrate this membrane and branch and rebranch in the space between the testicular follicles. A delicate network of loose fibrous connective tissue is present in the space between the testicular follicles.

The testicular follicles open into an enlarged portion of the distal end of the vas deferens, the so-called collecting reservoir, which is excentrically placed within the testis. Each testicular follicle does not always open separately into this collecting reservoir, but oftentimes two or more join with one another before opening into it.

A longitudinal section parallel to the surface of the testis shows that the epithelial layer of the collecting reservoir extends for a short distance into each testicular follicle. The epithelium consists of a layer of flattened cells, with cell boundaries indiscernible; each cell contains an ovoid nucleus. The epithelial cells rest upon a basement membrane. External to this membrane is a branching muscle layer, which continues for some distance on each testicular follicle. In our work upon the female reproductive organs of *Cimbex* (34) we found branching anastomosing muscles in the egg-tubes extending to the apex of the ovariole, being present in even the terminal filament.

Vas deferens: The vas deferens is made up of the following layers passing from without, inward:—1, a very much folded, peritoneal membrane; 2, a longitudinal branching muscle layer; 3, a muscle layer composed of transversely striated circular and oblique fibres; 4, a basement membrane and 5, an epithelial layer consisting of elongated cells with cell boundaries not discernible.

Seminal vesicle: With the exception of that region of the seminal vesicle, which is near the opening into the glandula muco-

sa, the histological structure is similar throughout its entire extent. The external peritoneal membrane covers a thin layer of longitudinal branching muscles. Within these are the circular muscles which often run obliquely. Next within, is a layer of epithelial cells with cell boundaries indiscernible, each cell containing an ovoid nucleus embedded in a granular protoplasm. The long axis of the nucleus is usually parallel with the free ends of the epithelial layer (Fig. 6, nep.) Within the lumen are bundles of spermatozoa which are embedded in a secretion.

Near the opening of the seminal vesicle into the glandula mucosa the structure of the former differs from that just described. The circular muscles are better developed, being from two to three layers in thickness. The cells gradually increase in size, cell boundaries are usually apparent and the nuclei assume a position at right angles to the free ends of the cells (Fig. 3, nc). These cells gradually pass over into the large cells of the glandula mucosa (Fig. 3, c.)

The openings of the seminal vesicles into the glandulae mucosae are directed posteriorly towards the ducts of these glands. On this account the sperms in passing from the seminal vesicles into the mucous glands probably never reach the distal end of the latter, but pass directly into the ducts of the glands and then into the ejaculatory ducts. In all our sections we did not find any sperms in the large swollen ends of the glandulae mucosae, a fact which supports the above view.

Accessory glands: A transverse section through the accessory glands shows that the epithelium is thrown into a number of large folds which almost fill the lumen (Fig. 3). The epithelial layer of the swollen distal part of the glands consists of exceedingly long cells with cell boundaries usually well defined (Fig. 4). Each cell contains a single ovoid nucleus with its long axis parallel to the same axis of the cell. The position of the nucleus varies within the cell; occasionally it is found near the free end, sometimes near the middle, but more often the nucleus is found near the basal region of the cell. These cells are glandular and contain numerous droplets of secretion (Fig. 4, g). The epithelium rests upon a thin basement membrane, outside of which are the muscle layers. Within the folds of the epithelial layer are branching muscles which are not so well developed as the external circular muscles. External to the circular muscles is a very thin delicate peritoneal membrane.

The glandular nature of the epithelial cells is shown by the presence of secretory processes which are somewhat similar to those that we have described and figured in the mid-intestine of *Cimbex* (33). Bordas (4) in his investigation upon the male reproductive organs of Coleoptera has described secretory processes in the accessory glands of a species of *Lucanus* and *Dorcus parallelipipedus*. In the process of secretion of *Cimbex* the free end of the cell becomes swollen causing it to project above the glandular cells at rest (Fig. 4, gl). The swollen mass elongates and assumes a more or less pyriform shape (Fig. 5, A). Further stages can be found in which the globules are still in direct continuity with the protoplasm of the cell, from which they originated, by a fine pedicel. Finally the globule becomes free by strangulation and floats in the lumen of the glandula mucosa (Fig. 5, B).

Since Zander (39) who has worked on the morphology of the male genital apparatus of various Hymenoptera, has described the ejaculatory ducts and penis of *Cimbex variabilis*, we made no further attempt to examine these parts in *Cimbex americana*.

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EXPLANATION OF PLATE XII.

All figures were drawn with a camera lucida.

FIG. 1. Dorsal view of reproductive organs: *t*, testis; *vd*, vas deferens; *sv*, seminal vesicle; *o*, entrance of seminal vesicle into glandula mucosa; *gm*, glandula mucosa; *ed*, ejaculatory duct. (X 16).

FIG. 2. Tracheae which hold the testis in its lateral position in the abdomen: *5s*, fifth abdominal stigma; *6s*, sixth abdominal spiracle; *tr*, trachea, which gives off a number of branches to the anterior end of the testis; *t*, testis; *vd*, vas deferens. (X17).

FIG. 3. Section through seminal vesicle and glandula mucosa, showing the opening of the former into the latter: *nc*, nuclei changing their direction; *sv*, seminal vesicle; *p*, peritoneal membrane; *o*, opening of the seminal vesicle into the glandula mucosa; *c*, cellular change; *bm*, branching muscles within the folds; *cm*, circular muscles. (X60).

FIG. 4. Exceedingly long cells of glandula mucosa: *gl*, swollen end of cell in the early process of forming a secretory globule; *g*, droplet of secretion; *n*, nucleus. (X650).

FIG. 5. Secretory processes: A, pyriform secretory process in direct continuity with the protoplasm of the cell from which it has originated; B, globule which has become free by strangulation. (X1300).

FIG. 6. Longitudinal section throughout the middle of the seminal vesicle: *cm*, circular muscles; *bm*, branching muscles; *nep*, nucleus. (X650).